Polar Oceans Biogeochemical Studies based on ECCO2 tools

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Thanks a lot to :

Mick Follows
Stephanie Dutkiewicz
Slide 2
Dimitris Menemenlis
Chris Hill
Jean-Michel Campin
Patrick Heimbach
Oliver Jahn

TALK OUTLINE

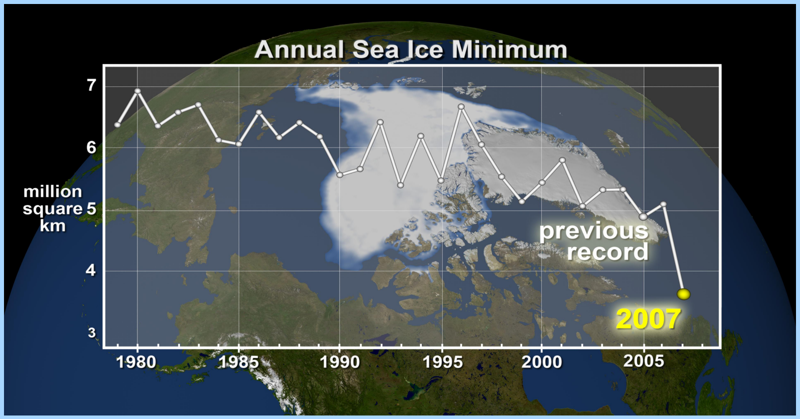
I) The Changing Arctic : Ocean C-Cycle Response

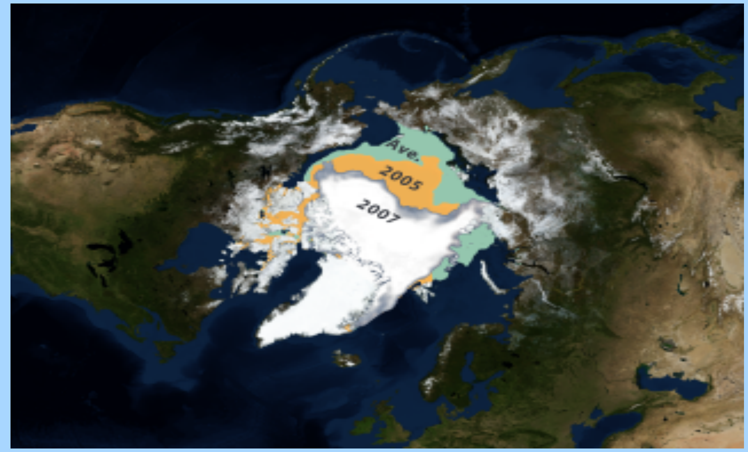
II) Model Description

III) Results

IV) Southern Ocean : Future work at SIO with ECCO2

Motivation : A Changing Arctic Ocean

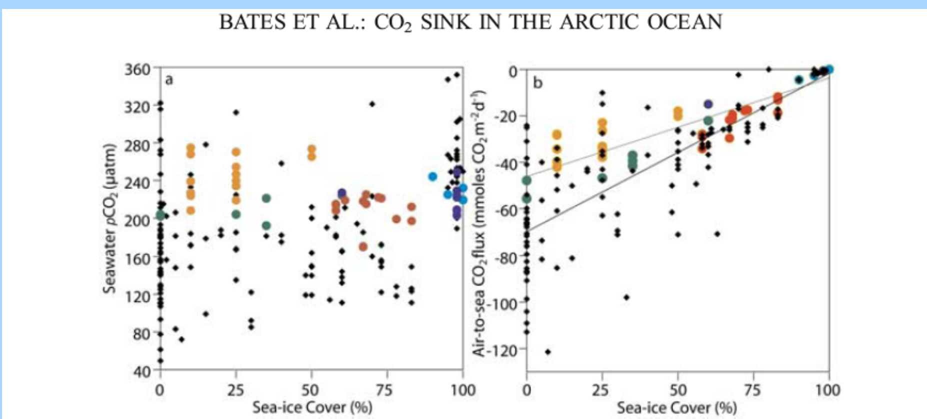




www.nasa.gov

Sea-Ice Cover **is the main factor driving the Arctic Ocean CO_2 uptake**

CO_2 Uptake increased from 24 TgC/yr to 66 TgC/yr in 3 decades

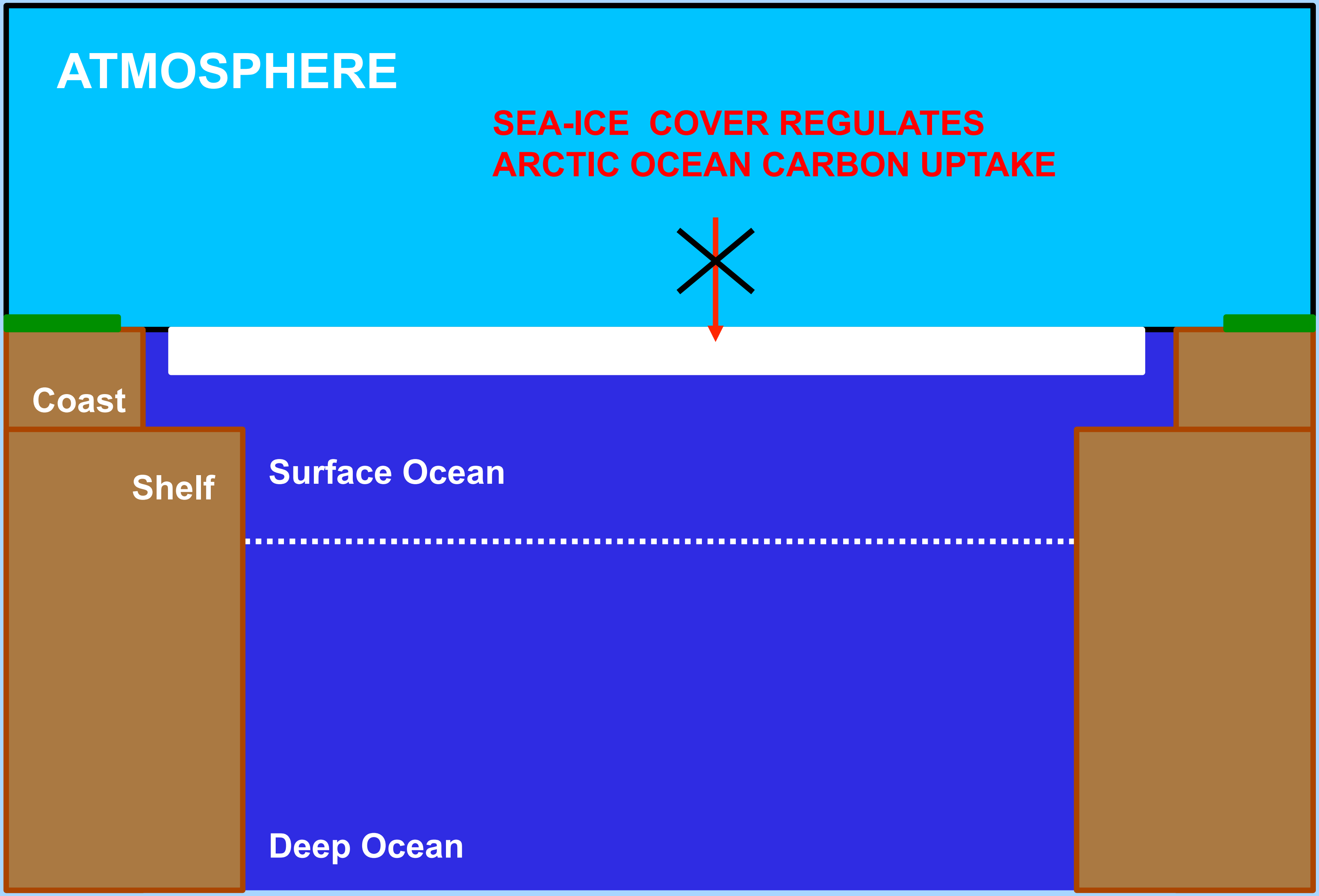


Bates *et al*., GRL, 2006

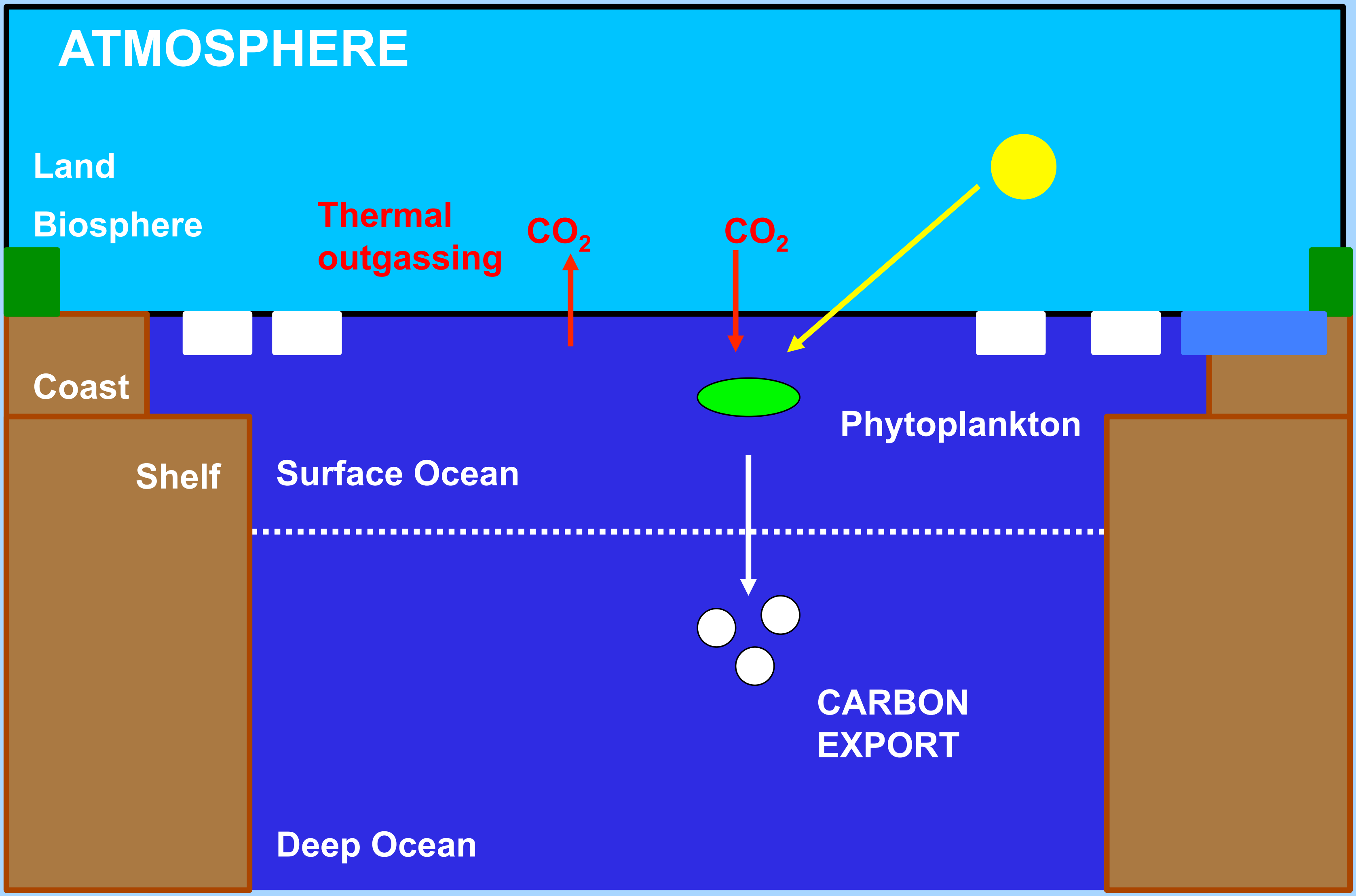
Large uncertainty **in the estimate of contemporay CO_2 sink (20-100 TgC/yr)**

Poor spatial-temporal coverage **of obs. of carbon data makes the estimates of the CO_2 sink HIGHLY UNCERTAIN.**

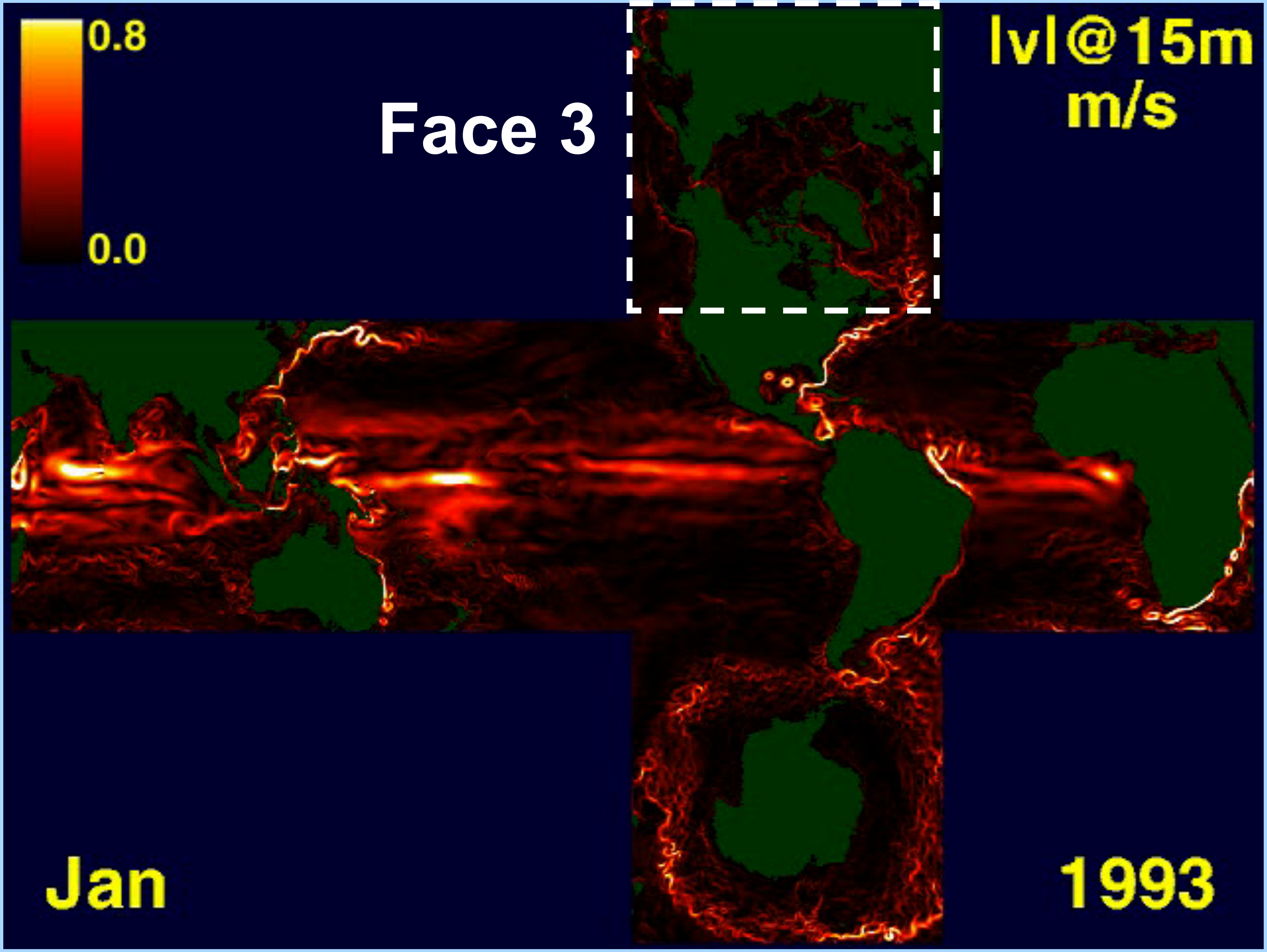
Arctic Ocean Carbon Cycle - Winter



Arctic Ocean Carbon Cycle - Summer



Regional Set-Up Cubed Sphere from ECCO2



Arctic Ocean Model

1) Ocean GCM (MITgcm, 18Km Horizontal Resolution, OBC)
2) Sea-Ice Model (Thermodynamics&Motion)
3) Ocean biogeochemical module (5+1 Tracers) :

DIC, ALK, O_2, DOP, PO4, + Riverine DOC (coupled to Ocean C-Cycle)

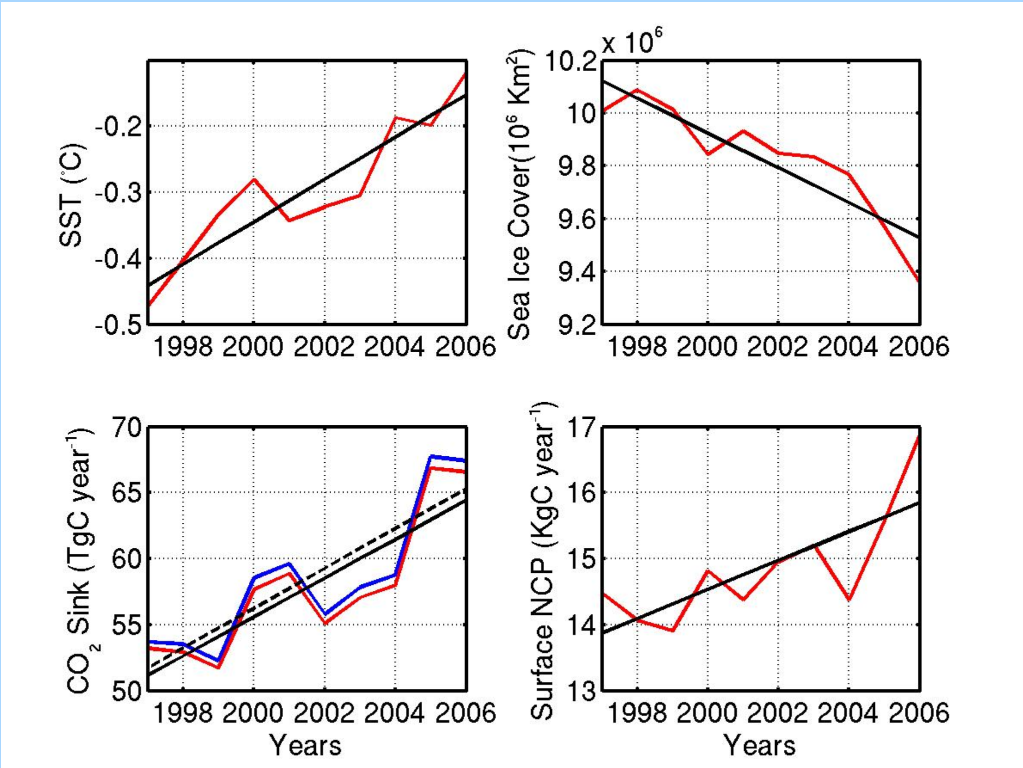
(*) Biologial production limited by LIGHT, PO_4

(*) Initialization : Observed physical and biogeochemical fields

(*) Re-analyzed NCEP Forcing 1995-2007 :
1992-1995 (spin-up) ==> 1996-2007 (study period)

Model Details in :
I) Riverine DOC dynamics :: Manizza *et. al* GBC, 2009.
II) RDOC/OCC Coupling :: Manizza *et al.* , 2009, Submitted to JGR-BGC
RDOC lowers by 10 % CO_2 uptake in the Arctic Ocean.

Arctic Ocean Carbon Cycle Response

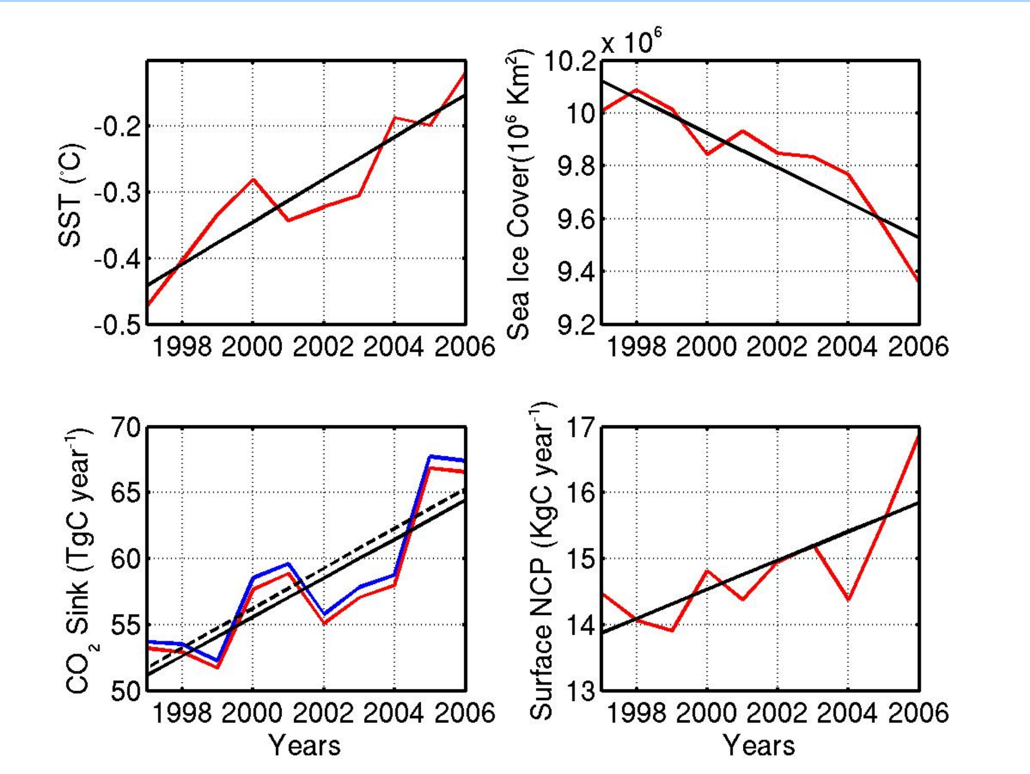


Resuts to be shown in :

I) Manizza *et. al* **, 2009, GBC, In prep.,**

II) McGuire *et al.* **, 2009, to Tellus B (ICDC 2009) - Full Arctic C-Budget**

Arctic Ocean Carbon Cycle Response



Sea Ice cover reduction increases the bioloical pump efficiency (major factor)

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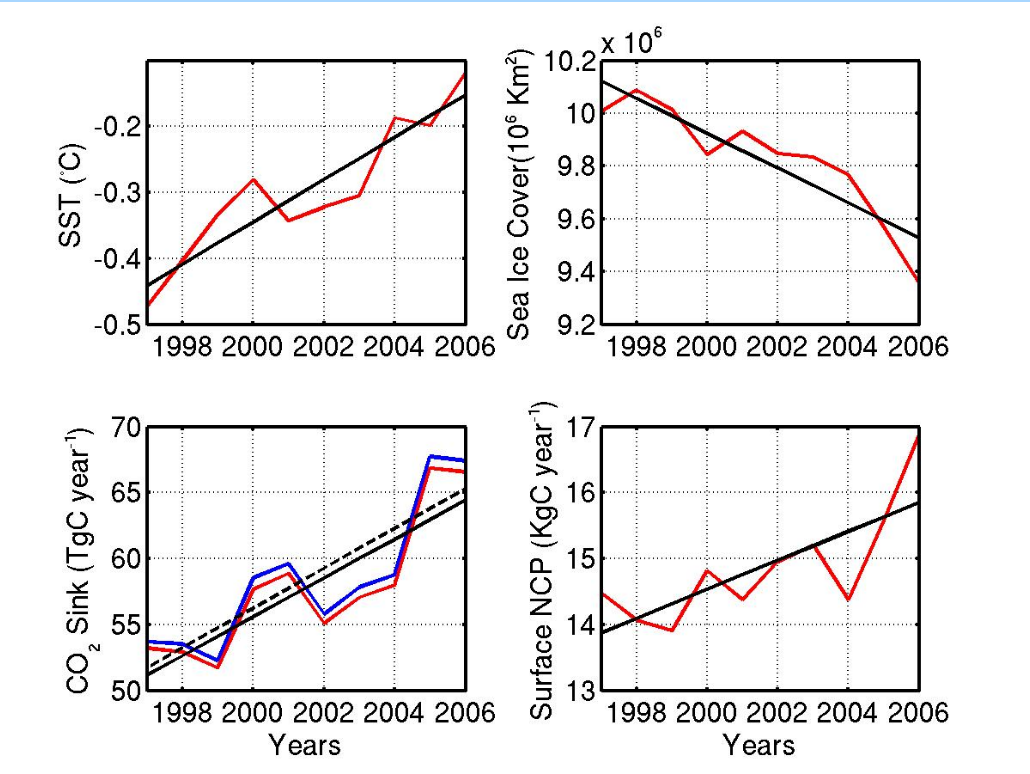

Sea Ice cover reduction increases the bioloical pump efficiency (major factor)

SST warming reduces the solubility pump efficiency (minor factor)

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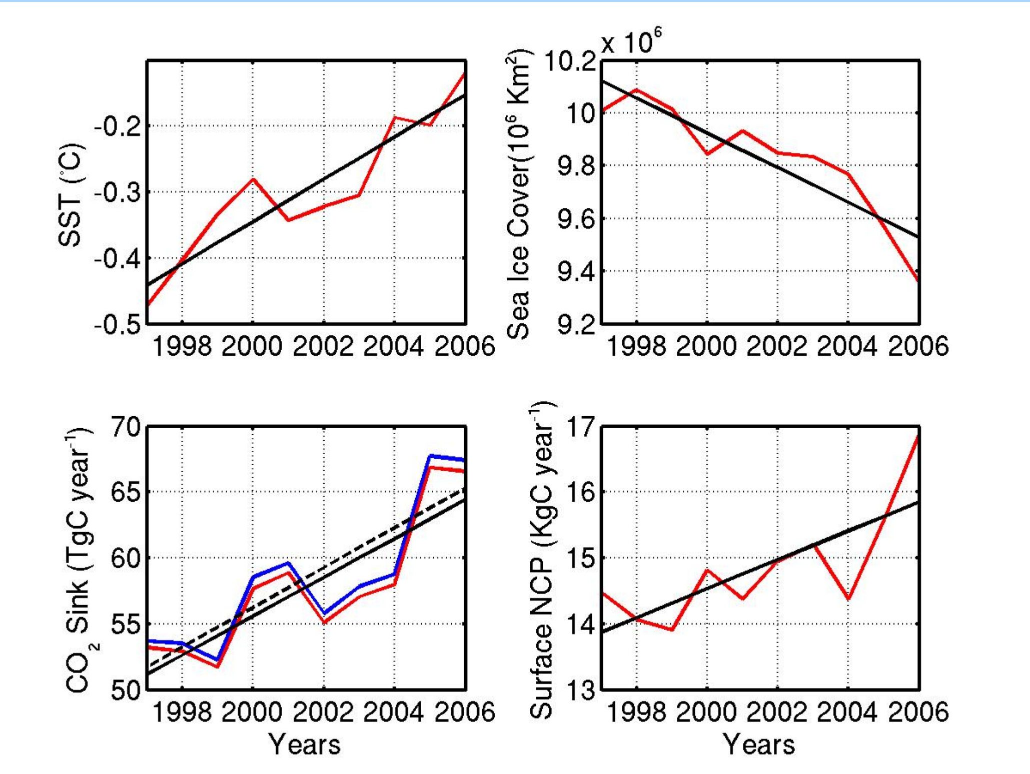

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Sea-Ice cover reduction is the main driver for the increase of CO_2 sink in the Arctic Ocean

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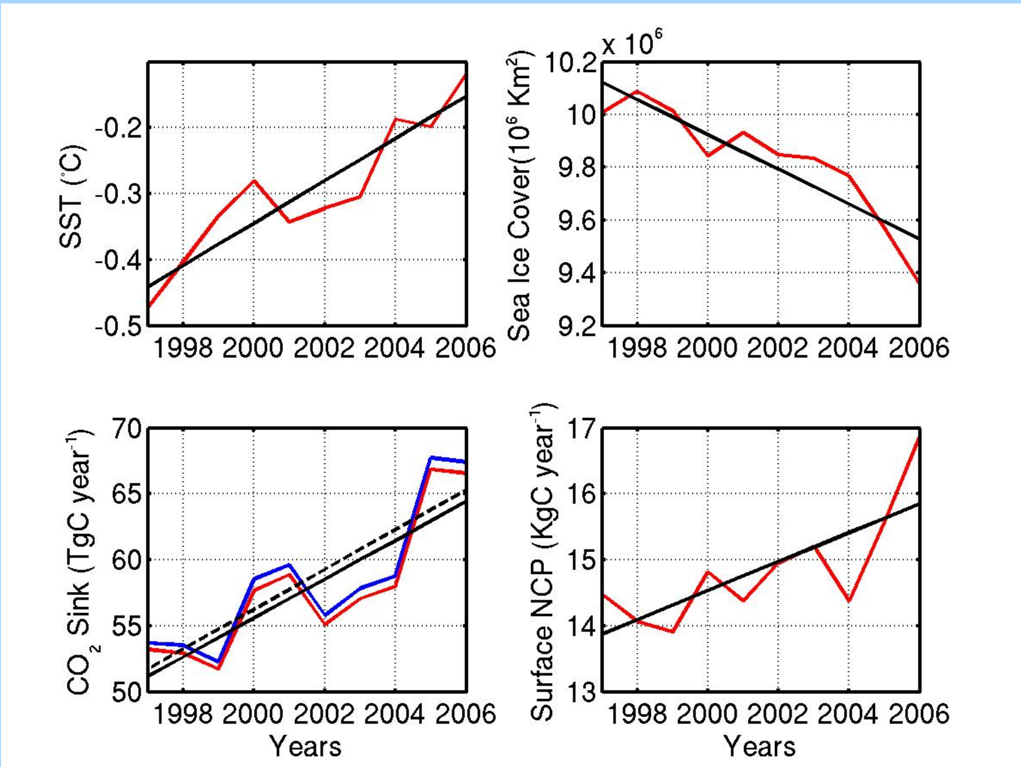
Arctic Ocean Carbon Cycle Response



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Sea-Ice cover reduction is the main driver for the increase of CO_2 sink in the Arctic Ocean

Future negative carbon-climate feedback in the Arctic Ocean

Resuts to be shown in :

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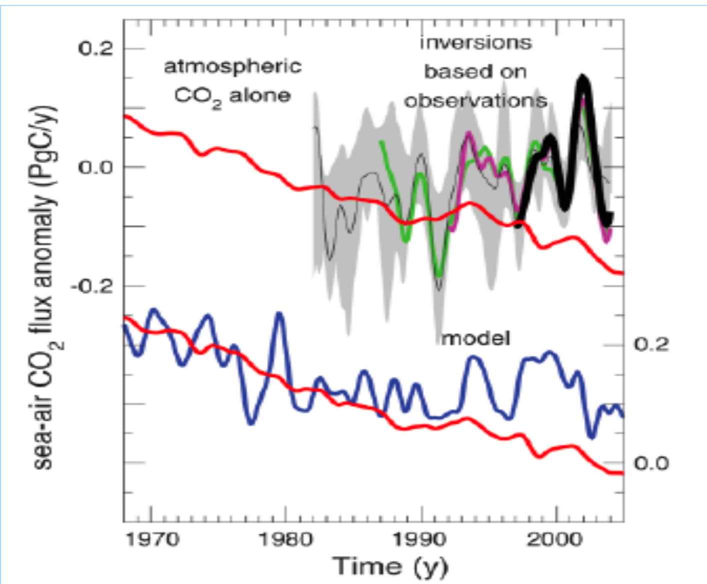
Saturation of the Southern Ocean CO_2 Sink Due to Recent Climate Change

Corinne Le Quéré,[1,2,3]* Christian Rödenbeck,[1] Erik T. Buitenhuis,[1,2] Thomas J. Conway,[4] Ray Langenfelds,[5] Antony Gomez,[6] Casper Labuschagne,[7] Michel Ramonet,[8] Takakiyo Nakazawa,[9] Nicolas Metzl,[10] Nathan Gillett,[11] Martin Heimann[1]

Based on observed atmospheric carbon dioxide (CO_2) concentration and an inverse method, we estimate that the Southern Ocean sink of CO_2 has weakened between 1981 and 2004 by 0.08 petagrams of carbon per year per decade relative to the trend expected from the large increase in atmospheric CO_2. We attribute this weakening to the observed increase in Southern Ocean winds resulting from human activities, which is projected to continue in the future. Consequences include a reduction of the efficiency of the Southern Ocean sink of CO_2 in the short term (about 25 years) and possibly a higher level of stabilization of atmospheric CO_2 on a multicentury time scale.



Increased wind stress lowers Ocean CO_2 uptake

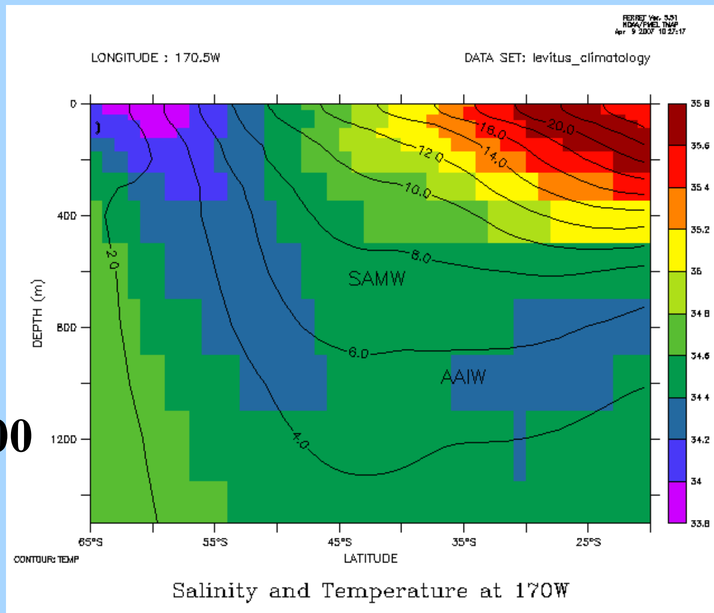
1) Results forcing dependent ?

2) What about role of key water masses formation in C uptake ?

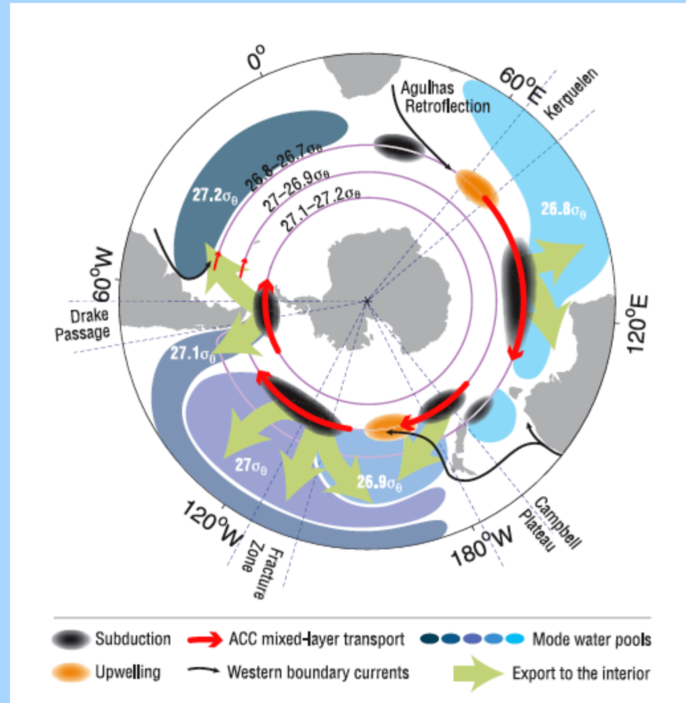
Ocean CO_2 Uptake by SAMWs/AAIWs

0

1200



65 S
25 S



Sallee' *et al*., JPO, *in press*

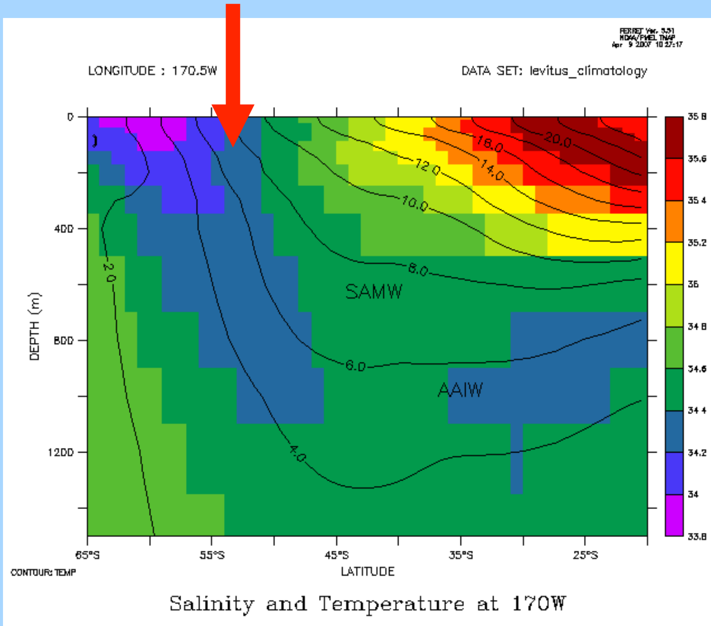
A. Fetter talk showed the physical setting of this study

Ocean CO_2 Uptake by SAMWs/AAIWs

CO_2

0

1200



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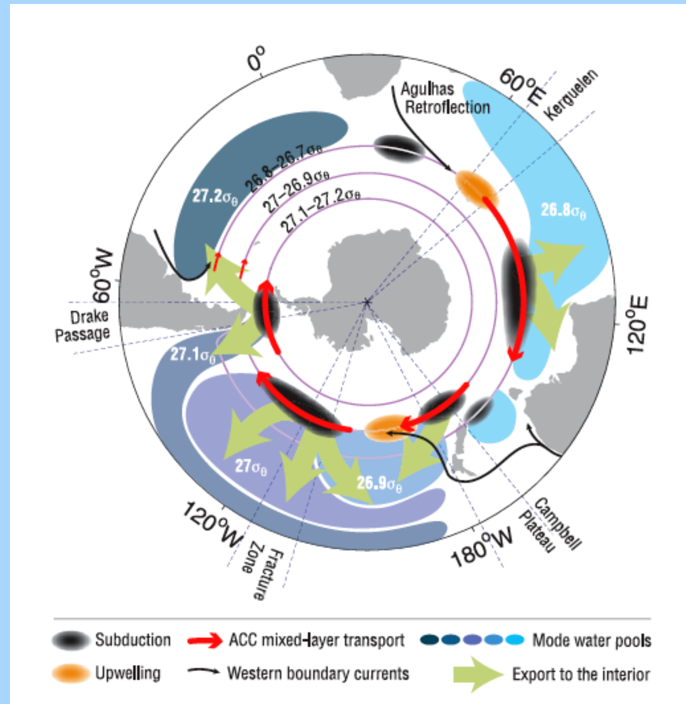

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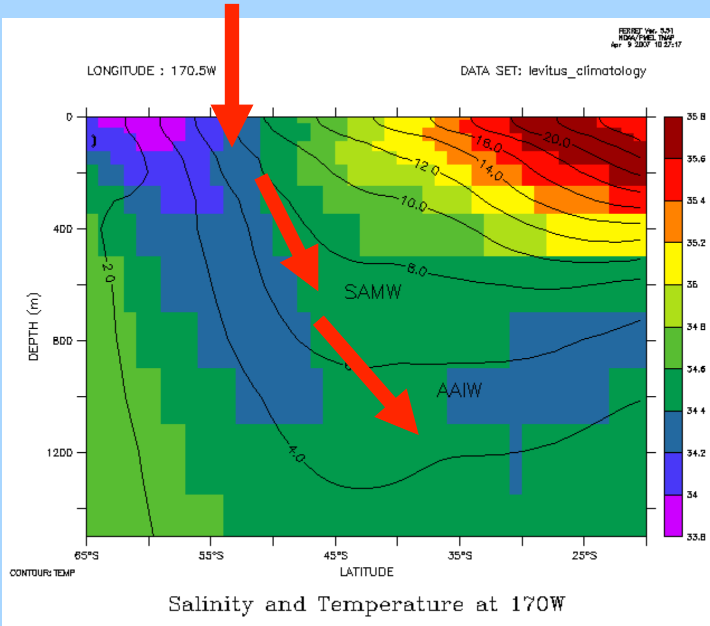

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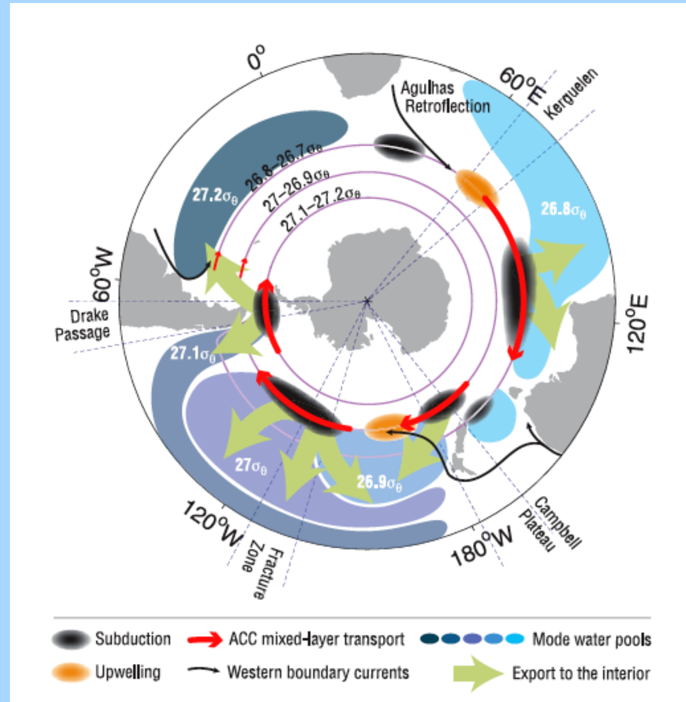

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Ocean CO_2 Uptake by SAMWs/AAIWs

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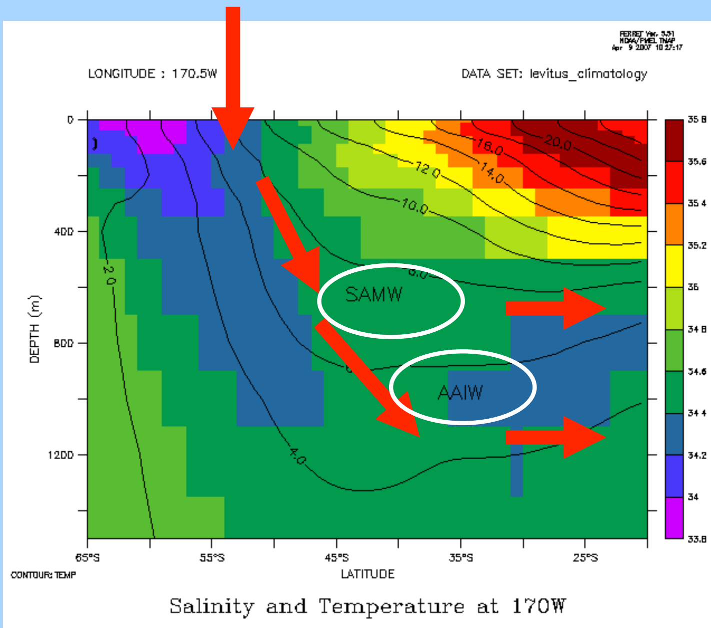
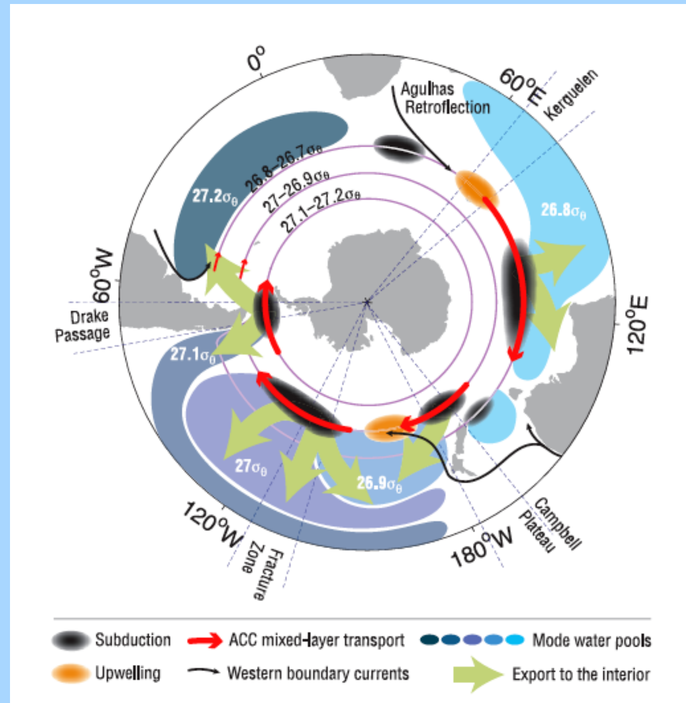


65 S 25 S



Sallee' *et al*., JPO, *in press*

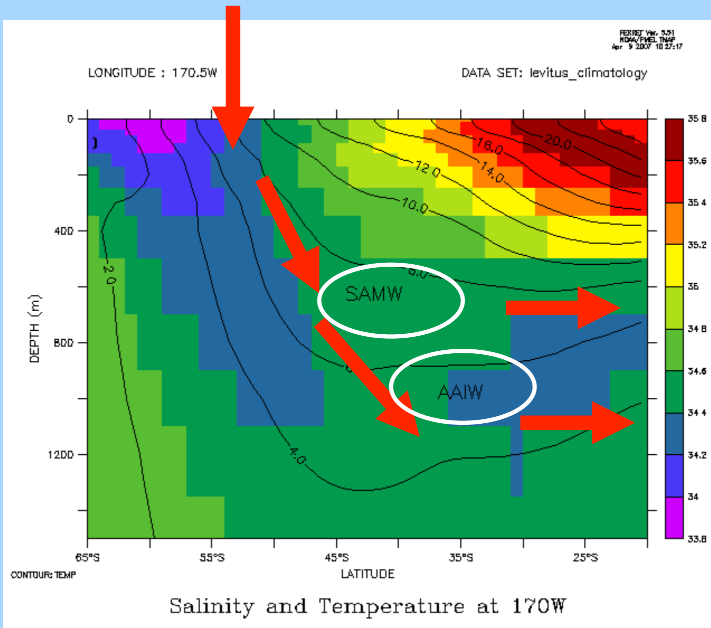
WM formation => Subduction => CO_2 Sequestration

Ocean CO_2 Uptake by SAMWs/AAIWs

CO_2

0

1200



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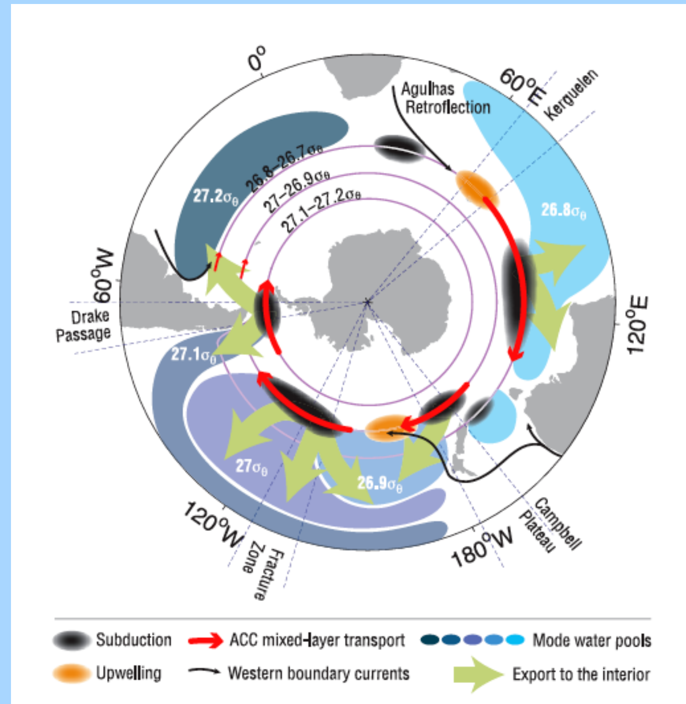


Sallee' *et al*., JPO, *in press*

S.O. CO_2 uptake depends on how WELL we represent SAMWs and AAIWs

Questions to answer with ECCO2 tools

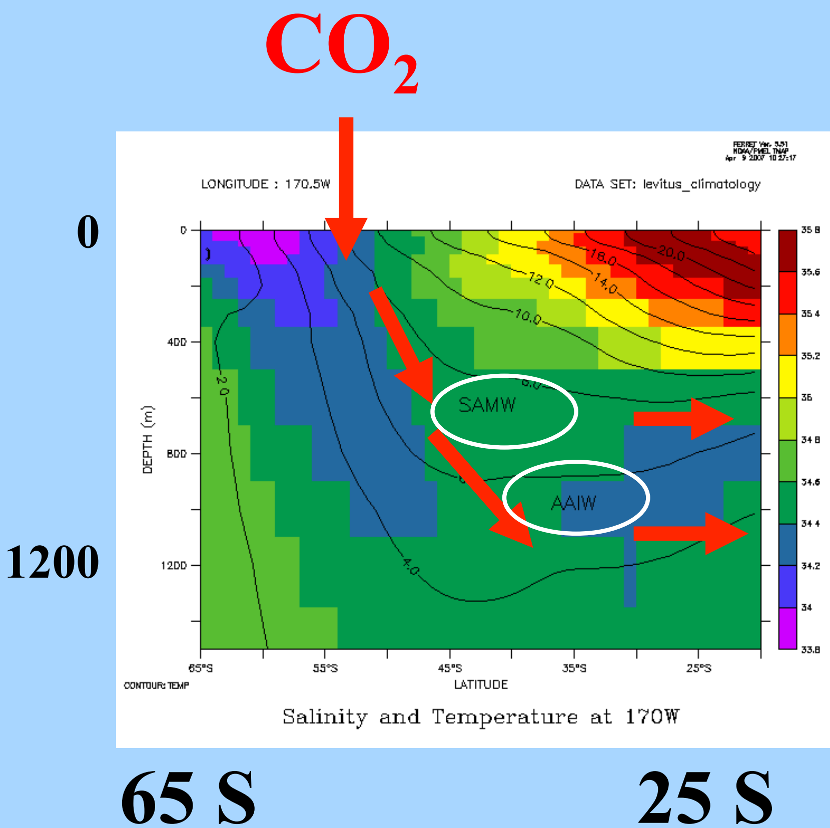
1) How important is realistic ocean physics for CO_2 uptake ?

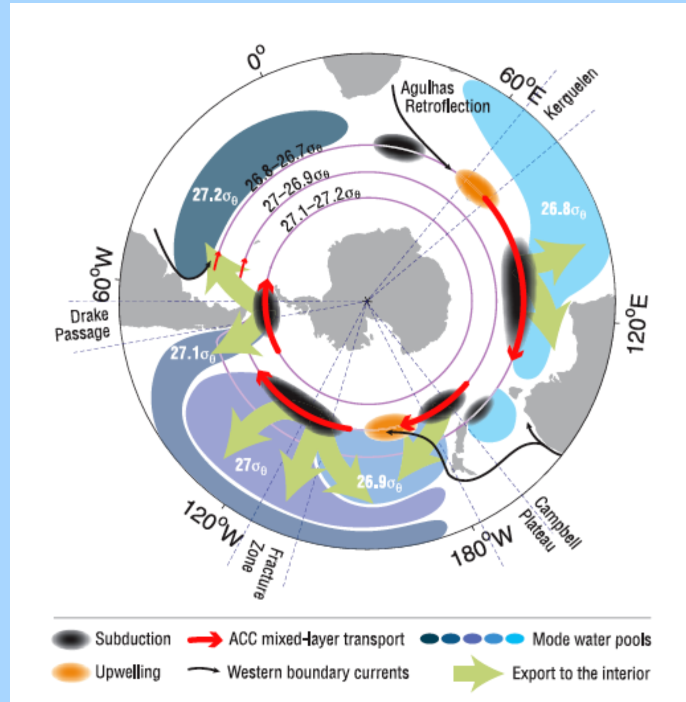
2) What is CO_2 uptake of AAIWs and SAMWs in ECCO2 ?

3) What is sensitivity of water masses formation rate to different atmospheric state and its impact on CO_2 uptake?

4) What is the difference in CO_2 uptake in the Southern Ocean among ECCO2, SOSE, and coarse global models for the recent past ?

Ocean CO_2 Uptake by SAMWs/AAIWs





Sallee' *et al.*, JPO, *in press*

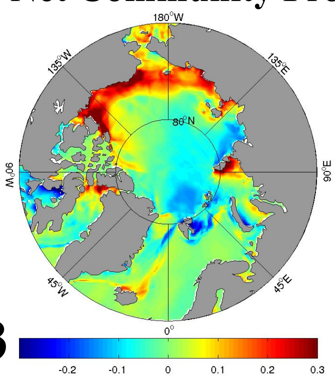
Use of SOSE/ECCO2 as reference oceanic state to drive CO_2 fluxes

Comparing constrained and constraiend CO_2 uptake estimates
Comparing with coarse global ocean models

Modeling & Observing Changes

Arctic biogeochemical model
2007 Minus 2006

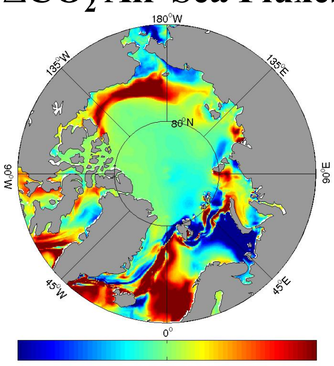
Surface Net Community Production



-0.3 **0.3**

($gC\ m^{-3}\ yr^{-1}$)

ΔCO_2 Air-Sea Fluxes

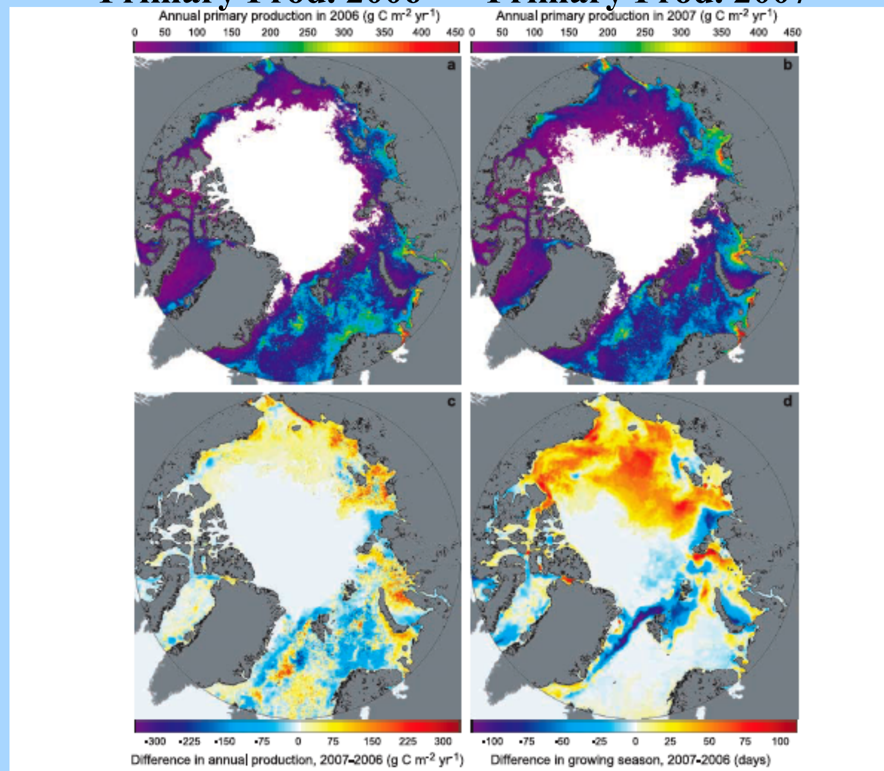


-5 **5**

outgassing **($gC\ m^{-2}\ yr^{-1}$)** **ingassing**

Satellite-based Observations

Primary Prod. 2006 **Primary Prod. 2007**



ΔPrimary Production ($gC\ m^{-2}\ yr^{-1}$)

ΔGrowing Season (days)

Arrigo *et al.*, GRL, 2008